3/prts

EMG CONTROL OF PROSTHESIS

insert a1

a1

Field of the invention

Cm

The invention relates to a method and a system for controlling prostheses such as artificial limbs ~~according to claim 1 and claim 12, respectively~~.

Background of the invention

The use of prostheses such as artificial limbs, e.g. hands, arms, legs, feet etc. for human beings who have lost a limb, is well-known.

Further, it is known that such artificial limbs may be constructed to provide (limited) movement of the limb in relation to the user or to provide movement between two parts of the limb, for example the turning of an artificial hand in relation to a corresponding artificial arm. These movements, which may be performed with only one or two degrees of freedom, may be body-powered, be powered electrically or controlled by special control arrangements which can be activated by the user, i.e. the wearer of the prosthesis.

Great efforts have been made to develop a user-friendly way of controlling the movement of artificial limbs. Thus, the use of electromyographic signals, also referred to as EMG signals in the following, have been utilized in prior-art to control prostheses or artificial limbs. In prior-art, these signals stemming from muscles which are activated, e.g. contracted or extended, have been picked up by contact electrodes, placed on the skin of a human being in places where residual muscles are present, e.g. in proximity of residual muscles. As one or more of these residual muscles is/are activated by the human being, EMG signals are generated. These electrical signals are picked up by contact electrodes and can be used as input to a control circuit for initiating movement of an artificial limb.

However, the contact electrodes will usually be placed for example on opposing sides of a lower arm or in such a manner that each electrode will pick up EMG signals from more than one muscle, i.e. a group of muscles. However, the signals picked up by these contact electrodes will still be able to provide a sufficient basis for controlling movements with one degree of freedom, for example the opening and closing of a hand in a palmer grasp mode, as the group of muscles on one side of the lower arm will provide a detectable signal of movement in one direction, for example closing of the hand, while the group of muscles on the other side of the lower arm will provide a detectable signal of movement in the other direction, for example opening of the hand. The user of such a prosthesis thus has to learn that once a certain group of muscles is activated, a palmer grip will be performed, and that the palmer grip will be relaxed and the hand will open when a certain other group of muscles is activated.

This has the disadvantage that some sort of training is required before the use of the prosthesis may be mastered by the user. Further, the movements that may be performed by the prosthesis are limited to relatively simple movements, e.g. opening and closing of a hand. However, it will also be possible to configure a prosthesis capable of performing more than one simple movement by having a switch-over function, for example a switch, which may be activated by the user, whereby the prosthesis may perform another movement, for example a pinch grip or a rotation of a wrist. This second movement will also be triggered by EMG signals from the same muscle groups as the first movement, and the activation by the user will thus be complicated and awkward, and the two different movements cannot be performed simultaneously.

The use of more than two sets of contact electrodes, i.e. electrodes applied to the skin of the user, for receiving EMG signals from different muscles or muscle groups will be difficult if not impossible in practice, as two contact electrodes placed for example on the same side of a lower arm will inevitably receive the same EMG signals emitted by the same muscles or muscle groups (cross talk). Consequently, it will be difficult to make a distinction between the signals received from these two contact electrodes and thus make control of two different movements by these signals impossible. Even if it were possible to place two contact electrodes on the same side of an arm in such a manner that the signals picked up by these contact electrodes

~~arm in such a manner that the signals picked up by these contact electrodes~~ would be distinctly different, i.e. not involving substantial cross talk, it would be necessary to teach the user to activate more than two muscles or muscle groups independently of each other in order to be able to achieve motions of the artificial limb with more than one degree of freedom. Hence, this would involve even more extensive training before the user would be able to master the use of the prosthesis satisfactorily.

Thus, it is an object of the present invention to provide a method and a system for controlling a prosthesis such as an artificial limb, whereby the movement of the prosthesis and/or parts thereof may be performed in a user-friendly manner by the user.

Another object of the invention is to provide a method and a system for controlling a prosthesis such as an artificial limb, whereby the movements of the prosthesis and/or part/parts thereof may be performed in a highly intuitive manner, e.g. a manner, which will be natural to the user.

It is a further object of the invention to provide a method and a system whereby relatively complex movements may be performed by the prosthesis and/or parts thereof.

These and other objects are achieved by the invention.

Summary of the invention

The present ~~As stated in claim 1, the~~ invention relates to a method of controlling a prosthesis such as an artificial limb, whereby electromyographic (EMG) signals are used to generate control signals for one or more prostheses such as artificial limbs, and whereby the electromyographic (EMG) signals are received by one or more sets of electrodes dedicated to a source of electromyographic (EMG) signals.

By using dedicated electrodes, i.e. electrodes designed and placed in such manner that the signals picked up by each of these sets of electrodes emanate from a predefined source, e.g. a certain muscle or a certain compartment within the muscle, elec-

tromyographic (EMG) signals originating from well-defined sources may be picked up.

Consequently, EMG signals stemming from a muscle which would be activated by a human being when this human being should desire to move a part of his body, e.g. a limb or a part of a limb replaced by a prosthesis, may be detected, picked up and used to control the corresponding prosthesis or corresponding part of the prosthesis.

Thus, the prosthesis or part of the prosthesis may be moved by the user in a highly intuitive way.

Further, it will be possible to perform relatively complex movements of a prosthesis or part/parts thereof as EMG signals may be received from muscles which would normally have been activated by the user of the prosthesis when performing the natural movements of the missing body part(s). These signals may thus be used to control the corresponding prosthesis parts, whereby the user may perform the desired movements intuitively, i.e. without having to learn to move a particular muscle group(s) in a particular way and/or without having to activate switch-over mechanisms etc.

A further advantage of the invention is related to environmental control, as the EMG control method may be applied for controlling light, appliances etc, which the user desires to control, e.g. turn on and off. Such an environmental control function may be configured in relation to the EMG control method for controlling a prosthesis, whereby the user would be able to control such appliances, for example via wireless control, without actually having to manipulate a control means, e.g. a switch.

The electrodes are constituted by sets of electrodes. In order to pick up an electrical signal, e.g. an electrical potential, a measurement or detection has to be made in at least two (spatially) different places in order to achieve a potential difference. Thus, at least two electrodes constitute a set of electrodes. Evidently, such a set of electrodes may be configured as a unit, whereby the distance between the two measuring

or detection points of the set of electrodes is predefined and kept at a constant by the unit, or the electrodes may be separate parts.

The one or more sets of dedicated electrodes may preferably~~, as stated in claim 2,~~ be placed subcutaneously, epimesially or intramuscularly, whereby it is ensured that relatively strong EMG signals from the corresponding muscle will be received by the electrode and that these signals will not be influenced by signals stemming from other sources, e.g. other muscles (cross talk).

Further, said one or more sets of dedicated electrodes may be implanted in a muscle or muscles~~, as stated in claim 3,~~ whereby the EMG signals will be received by the electrodes in a relatively powerful form without any cross talk from other sources of EMG signals.

The muscles, in which the sets of electrodes are implanted, may for example be residual muscles related to a missing part of the body replaced by a prosthesis, e.g. muscles in an arm of a below elbow (BE) amputee. However, the sets of electrodes may be implanted in any residual limb or other muscles as desired in order to improve the EMG signal pattern discriminality. For example, a muscle in a shoulder part of an amputee may provide resourceful EMG signal information relating to the desired movements of for example a hand or an arm.

Preferably~~, as stated in claim 4,~~ the electromyographic (EMG) signals from said one or more sets of dedicated electrodes may be transmitted to signal processing means by wireless transmission, whereby the disadvantages and/or discomfort associated with signal wires protruding through the skin of the user may be avoided.

In a preferred embodiment~~, as stated in claim 5,~~ the electromyographic (EMG) signals from said one or more sets of dedicated electrodes are processed by signal processing means, whereby control signals for the artificial limb(s) are produced, said signal processing means utilizing a pattern recognition method. Hereby, the control signals may be produced in an advantageous manner and the control signals may

consistently lead to the desired movements of the prosthesis and/or part/parts thereof irrespective of the fact that the EMG signals may vary in form and/or amplitude.

The ~~As stated in claim 6, the~~ control signals of the artificial limb(s) may be generated by utilizing an artificial neural network (ANN), whereby the pattern recognition method may be performed in a particularly advantageous manner.

The ~~As stated in claim 7, the~~ electromyographic (EMG) signals may preferably be received by four or more sets of dedicated electrodes, located in relation to at least four muscles, or combinations of distinct functional muscle compartments, whereby a sufficient number of distinct EMG signals may be provided in order to achieve at least four different movements of a limb or part/parts thereof.

The ~~As stated in claim 8, the~~ method may be utilized to control an artificial arm and/or hand, whereby one or more sets of electrodes is/are placed in relation to at least the following muscles: Flexor Digitorum, Extensor Digitorum, Flexor Pollicis Longus and Extensor Pollicis Longus. This may provide at least four different movements of the artificial arm or part/parts thereof, for example closing and opening of a hand in a palmer grasp mode and closing and opening of a hand in a lateral grasp (also referred to as a key grip) mode.

The ~~As stated in claim 9, the~~ method may be utilized to control an artificial arm and/or hand, whereby one or more sets of electrodes are placed in relation to at least the following muscles: Flexor Digitorum, Extensor Digitorum, Flexor Pollicis Longus, Extensor Pollicis Longus, Pronator Teres, Supinator, Flexor Carpi Radialis and Extensor Carpi Radialis. Hereby, an artificial arm with an even larger degree of freedom may be controlled in a user-friendly and highly intuitive manner by the user. An artificial arm may for example be configured for opening/closing the hand and performing a palmer or a key grip, rotating or flexing the wrist, extending or bending the fingers and the thumb (selectively) etc., making all these functions controllable by the amputee (the user) in a natural and highly intuitive manner.

Two ~~As stated in claim 10, two~~ or more dedicated sets of electrodes may be placed in relation to at least one muscle, said two or more sets of dedicated electrodes being placed in relation to different parts of said at least one muscle. Hereby, EMG signals from different parts of the muscle may be picked up. These EMG signals may differ and may be used to achieve greater reliability and/or even more complex and detailed patterns of movements performed by a prosthesis such as an artificial limb.

Finally, ~~as stated in claim 11,~~ electroneurographic (ENG) signals may be received by one or more separate sets of ENG-electrodes and these ENG-signals may be used as complimentary signals for generating control signals. Hereby, further information concerning a desired movement may be provided and used to control a prosthesis. In cases where EMG signals may not be recorded, for example EMG signals stemming from muscles, which are absent, in particular the intrinsic muscles of the hand, it may be possible to record corresponding ENG signals, for example from the trunk nerves in the upper arm. These ENG signals will contain information complimentary to the EMG signals, whereby improved control of a prosthesis is provided. The ENG signals from the nerves may be provided in a number of ways known to a person skilled in the art.

The invention also relates to a system for controlling a prosthesis, such as an artificial limb~~, as claimed in claim 12~~. Electromyographic ~~According to claim 12, electromyographic~~ (EMG) signals are used to generate control signals for one or more artificial limbs and the system comprises one or more sets of dedicated electrodes, each placed in relation to a muscle, for receipt of the electromyographic (EMG) signals.

By using dedicated electrodes, i.e. electrodes designed and placed in such manner that the signals picked up by each of these electrodes emanate from a predefined source, e.g. a certain muscle or a certain compartment of a muscle, electromyographic (EMG) signals originating from well-defined sources may be picked up.

Consequently, EMG signals stemming from a muscle which would be activated by a human being when this human being would move a part of his body, e.g. a limb or a

part of a limb replaced by a prosthesis, may be detected, picked up and used to control the corresponding prosthesis or corresponding part of the prosthesis.

Thus, the system allows the user to move the prosthesis or part of the prosthesis in a highly intuitive way.

Further, by using the system, it will be possible to perform relatively complex movements of a prosthesis or part/parts thereof, as EMG signals may be received from muscles that would normally have been activated by the user of the prosthesis when performing the natural movements of missing body parts. These signals may thus be used to control the corresponding prosthesis parts, whereby the user may perform the desired movements intuitively, i.e. without having to learn to move particular muscle groups in a particular way and/or without having to activate switch-over mechanisms etc.

A further advantage of the system is related to environmental control, as the EMG control system may be applied for controlling light, appliances etc., which the user desires to control, e.g. turn on and off. Such an environmental control function may be incorporated in the EMG control system for controlling a prosthesis, whereby the user would be able to control such appliances, for example via wireless control, without actually having to manipulate a control means, e.g. a switch.

According to the preferred embodiment, ~~as stated in claim 13~~, the one or more dedicated sets of electrodes of the system may be configured for subcutaneous, epimesial or intramuscular use, whereby it is ensured that relatively strong EMG signals from the corresponding muscle will be received by the electrode and that these signals will have a relatively high signal/noise ratio without interference from signals stemming from other sources, e.g. other muscles (cross talk).

Further, ~~as stated in claim 14~~, said one or more sets of dedicated electrodes of the system may be configured for implantation in a muscle or muscles, whereby the

EMG signals will be received by the electrodes of the system in a relatively powerful form and without cross talk from other sources of EMG signals.

The muscles in which the sets of electrodes are implanted may for example be residual muscles related to a missing part of the body replaced by a prosthesis, e.g. muscles in an arm of a below elbow (BE) amputee. However, the sets of electrodes may be implanted in any residual limb or other muscles as desired in order to improve the EMG signal pattern discriminality. For example, a muscle in a shoulder part of an amputee may provide resourceful EMG signal information relating to the desired movements of for example a hand or an arm, whereby the functionality of the system may be enhanced.

The ~~As stated in claim 15, the~~ system may comprise means for transmitting the electromyographic (EMG) signals from said one or more sets of dedicated electrodes to signal processing means by wireless transmission, whereby the disadvantages and/or discomfort associated with signal wires protruding through the skin of the user may be avoided.

According to a preferred embodiment of the system, ~~and as stated in claim 16,~~ the system comprises signal processing means for producing control signals for the artificial limb(s), said signal processing means utilizing a pattern recognition method. By this system, the control signals may be produced in an advantageous manner whereby the control signals may consistently lead to the desired movements of the prosthesis and/or part/parts thereof irrespective of the fact that the EMG signals may vary in form and/or amplitude.

The ~~As stated in claim 17, the~~ system may comprise an artificial neural network (ANN) for generating control signals for the artificial limb(s), whereby the pattern recognition method may be performed by the system in a particularly advantageous manner.

Preferably, ~~as stated in claim 18,~~ the system may comprise four or more sets of dedicated electrodes placed in relation to at least four muscles, or combinations of func-

tional distinct muscle compartments, for receipt of electromyographic (EMG) signals. By this system, a sufficient number of distinct EMG signals may be provided in order to achieve at least four different movements of a limb or part/parts thereof.

The ~~As stated in claim 19, the~~ system may be utilized to control an artificial arm and/or hand wherein one or more electrodes is/are placed in relation to at least the following muscles: Flexor Digitorum, Extensor Digitorum, Flexor Pollicis Longus and Extensor Pollicis Longus. This system may provide at least four different movements of the artificial arm or part/parts thereof, for example closing and opening of a hand in a palmer grasp mode and closing and opening of a hand in a lateral grasp (also referred to as a key grip) mode.

The ~~As stated in claim 20, the~~ system may be utilized to control an artificial arm and/or hand, wherein one or more electrodes is/are placed in relation to at least the following muscles: Flexor Digitorum, Extensor Digitorum, Flexor Pollicis Longus, Extensor Pollicis Longus, Pronator Teres, Supinator, Flexor Carpi Radialis and Extensor Carpi Radialis. By this system, an artificial arm with an even larger degree of freedom may be controlled in a user-friendly and highly intuitive manner by the user. An artificial arm may for example be configured for opening/closing the hand and performing a palmer or a key grip, rotating or flexing the wrist, extending or flexing the fingers and the thumb (selectively) etc., making all these functions controllable by the amputee (the user) in a natural and highly intuitive manner.

The system may~~, as stated in claim 21,~~ advantageously comprise two or more sets of dedicated electrodes placed in relation to at least one muscle, wherein said two or more dedicated electrodes are placed in relation to different parts of said at least one muscle. Hereby, EMG signals from different parts of the muscle may be picked up by the system. These EMG signals may differ and may be used by the system to achieve an even more complex and detailed pattern of movements performed by a prosthesis such as an artificial limb.

Finally, ~~as stated in claim 22,~~ the system may comprise one or more sets of electroneurographic (ENG) electrodes for receiving electroneurographic (ENG) signals which may be used as complimentary signals for generating control signals.

Hereby, further information concerning a desired movement may be provided and used to control a prosthesis. In cases where EMG signals may not be recorded, for example EMG signals stemming from muscles which are absent, in particular the intrinsic muscles of the hand, it may be possible to record corresponding ENG signals, for example from the trunk nerves in the upper arm. These ENG signals will contain information complimentary to the EMG signals when generating control signals, whereby an improved control system for a prosthesis is provided. The ENG electrodes for recording ENG signals from the nerves may be configured in a number of ways known to a person skilled in the art.

Figures

The invention will be described below with reference to the drawings of which

fig. 1 shows a cross section of the lower part of an arm illustrating the suggested positioning of dedicated electromyographic (EMG) electrodes according to the invention,

fig. 2 shows an example of an electromyographic (EMG) signal picked up by a set~~s~~ of EMG electrodes according to the invention,

fig. 3 illustrates a system for recording, processing and evaluating EMG signals from a human being, and

fig. 4 illustrates a block diagram, wherein a pattern recognition circuit with artificial neural networks ~~are~~ is utilized to control an artificial limb.

Detailed description

Fig. 1 illustrates a cross section of the right forearm of a human being, for example a human being who has lost a hand and perhaps part of the lower arm. The cross sec-

tion shown in fig. 1 thus illustrates the residual muscles in the remaining part of the lower arm.

The cross section might be an image of the arm provided by an MRI (magnetic resonance imaging) scanner, and the MRI technique may also be employed when implanting the electrodes according to the invention.

The view is from distal to proximal with the Dorsal surface at the top and with the Radial surface to the left of the figure. The figure indicates the relevant residual muscles for recording electromyographic (EMG) signals:

Flexor digitorum profundus 1,
Flexor digitorum superficialis 2,
Extensor digitorum 3,
Flexor pollicis longus 4,
Extensor pollicis longus 5,
Supinator 6,
Pronator teres 7,
Flexor carpi radials8,
Flexor carpi ulnaris 9,
Extensor carpi radialis brevis 10,
Extensor carpi radialis longus 11,
Extensor carpi ulnaris 12.

From the figure, it may be observed that several of these muscles are placed relatively deep in the arm and are not directly accessible. EMG signals from these muscles will thus be difficult to obtain with surface electrodes. In particular, Extensor pollicis longus 5, Supinator 6 and Flexor pollicis longus 4 are inaccessible and cannot be recorded by using surface mounted electrodes.

A selection of palmer grip versus key grip can be achieved by analyzing the EMG activity of four muscle groups:

Finger flexors: This can be Flexor digitorum profundus 1 or Flexor digitorum superficialis 2.

Finger extensors: This can be extensor digitorum 3.

Thumb flexor: This can be Flexor pollicis longus 4.

Thumb extensor: This can be Extensor pollicis longus 5.

A selection of the function of wrist movements (flexion; extension; pronation and supination) can be achieved by analyzing the EMG activity of four muscle groups:

Wrist supination: This can be Supinator 6.

Wrist pronation: This can be Pronator teres 7.

Wrist flexion: This can be Flexor carpi radials 8 or Flexor carpi ulnaris 9.

Wrist extension: This can be Extensor carpi radialis brevis 10, Extensor carpi radialis longus 11 or Extensor carpi ulnaris 12.

Electrodes for receiving electromyographic (EMG) signals from the muscles may be implanted in these muscles, for example in special parts of these muscles, where the signals may be picked up in a relatively strong form, with or without only a small amount of cross talk.

The electrodes may be monopolar, bipolar,tripolar etc. The electrodes may be placed percutaneously, whereby the signal wires will have to protrude through the skin of the user. This has some disadvantages such as the risk of infection and the discomfort to the user which makes the use of electrodes, which are totally implanted, preferable.

When totally implanted electrodes are used, the signals may be transmitted for example by telemetry by electromagnetic, optical or other means, to the surface of the arm and/or to the processing means of the signals.

Fig. 2 illustrates an example of a EMG signal picked up from a residual muscle in a lower arm. The signal from the EMG electrode has been processed, e.g. amplified (1000 – 10000), band-pass filtered (10 Hz – 1 kHz) and sampled (2 kHz). Further, the signal has been processed in order to remove DC-offset and motion artifacts (digital high pass, Butterworth order 4, 20 Hz). Finally, the signal has been full-wave rectified and a moving average signal has been provided (over a 25 ms sliding window) before the signal has been processed in order to determine an onset.

This has been done by applying a 200 ms sliding window 21 to the moving average signal. If the number of samples in this 200 ms window 21 exceeds an appropriate threshold value for at least 175 ms (not necessarily consecutively), the first point of this window 21 is labeled as the onset 22. Initial spikes 23 will thus not have any influence on the detection of the onset event 22.

Following the detection of an onset event, a search for an offset event, for example when the number of samples below the appropriate threshold exceeds 150 ms, takes place.

This is only an example of the signal processing to determine onset and offset. Other algorithms may be applied in connection with the invention.

Fig. 3 illustrates a system for recording, processing and evaluating EMG signals from a human being, for example in order to examine the signals from implanted electrodes, and for optimizing the positioning of electrodes, the signal processing means or the control means or in order to train a user of a system according to the invention.

A human being 30 who has lost a hand has had a number of EMG electrodes implanted in the forearm 31. These are connected by means of wires 32 to a signal processing means 33 comprising amplifiers and filters. The output from the processing means 33 is delivered to a data acquisition board and computer 34, where the

signals are stored and/or visualized. Further, the system comprises a computer 35 with a screen, on which an animation target 36 is shown.

The animation target 36 is a hand which may perform different movements, grips, etc., and the amputee 30 is asked to mimic with his phantom hand the animations performed by the hand 36. The signals may be stored by the computer 34, and the recorded signals corresponding to the movements and grips intended by the amputee may be used to configure a system according to the invention. In particular, the system illustrated in fig. 3 may be utilized for training artificial neural networks in order to configure a control system according to the invention and in order to individualize such a system.

Fig 4 illustrates a control system according to the invention wherein artificial neural networks (ANN) are utilized. A prosthesis 41 in the form of an artificial hand 41 is illustrated as the object to be controlled by the system. A number of EMG electrodes 43a – 43n are illustrated, each receiving EMG signals 42a – 42n, respectively. The output signals 44a - 44n are amplified, band-pass filtered and transmitted, for example by telemetry by electromagnetic, optical or other means, to a signal processing means 45, comprising for example additional amplifiers, filters etc. The output 46 from this processing means is led to a pattern recognition circuit 47 comprising for example artificial neural networks, wherein the signals are processed in order to determine which movements and/or grips are desired by the user.

From the pattern recognition circuit 47, a signal is sent to a control circuit 48 containing for example power and control circuits, and finally an output signal is led to the driving means 49 of the artificial hand 41.

In addition to the EMG electrodes 43a – 43n delivering signals 44a – 44n to the signal processing means 45, a number of ENG (electroneurographic) electrodes (not shown) may be utilized in connection with the system, providing additional information of the intended movements.

In this case, the invention has been described in relation to an artificial limb in the form of a hand. Evidently, the invention may be used in relation to prostheses in general, e.g. artificial arms, legs, feet, etc.

Further, the invention can be applied for environmental control in addition to control of prostheses. For example, a user may utilize the system to turn lights on and off, to open and close power-controlled doors, to control communication means, to control input to communication means, e.g. computers, to control vehicles, to control appliances etc.